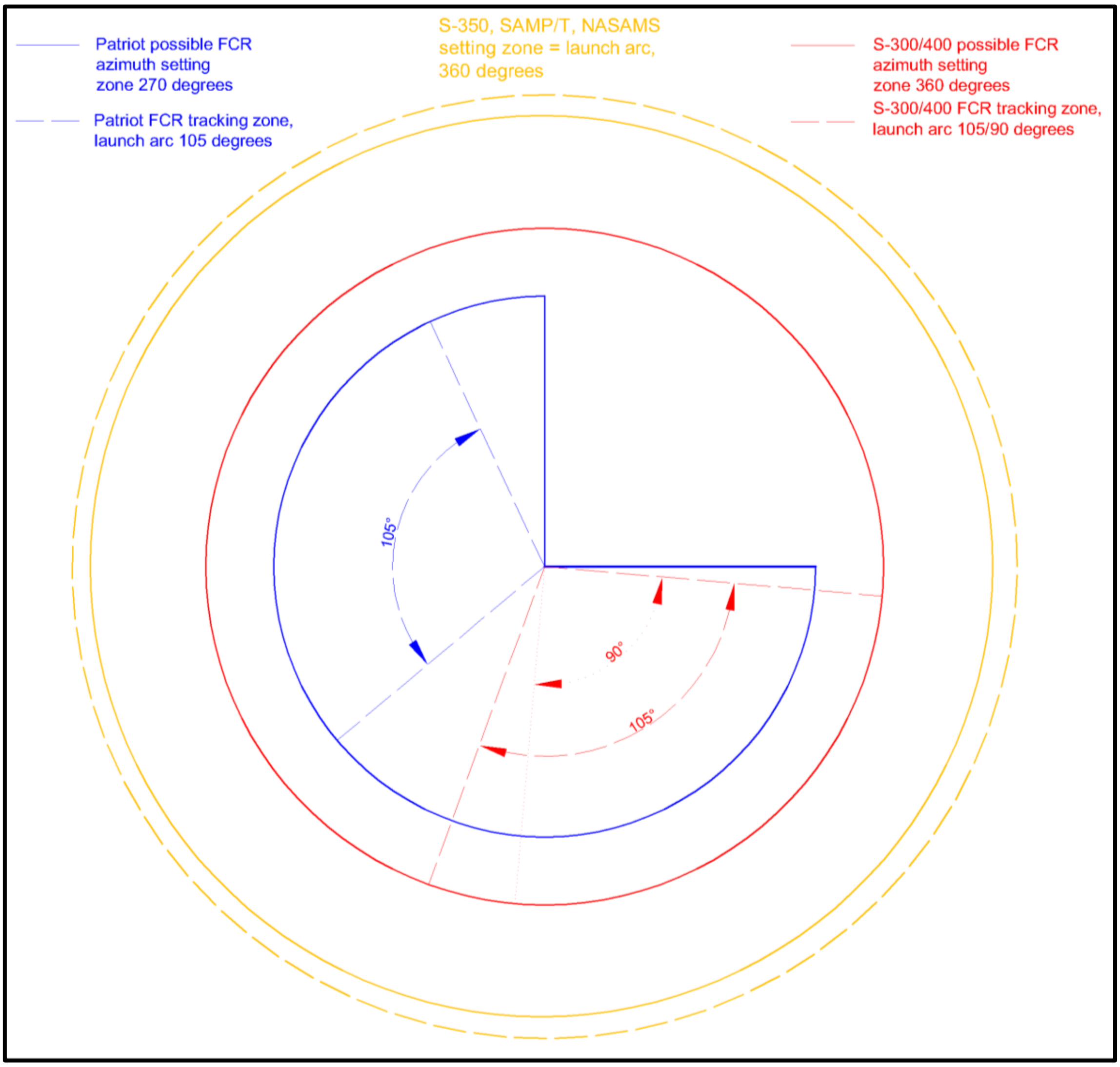
SAMs in XXI. Century, future of radar guided SAMs

So far all presented radar guided SAM systems in previous chapters have a common feature all of them have fire control radar (or we can call them guidance station) which restrict their firing arc (launch and guidance zone). Even the most advanced and long range systems (S-300 and Patriot) have only 90-105 degrees fire arc regardless the radar can be set to any direction for most of them.



(Patriot and S-25 Berkut are the exceptions. Berkut only with lots of static radars had 360 firing arc concerning as the whole ring around Moscow while Patriot has 270 degree azimuth setting limitation.)

The appearance of active radar homing guidance made possible developing a new approach for SAMs. Using new generation of target acquisition radars – in elevation with PESA/AESA scan in azimuth mechanical scan (rotation) – a new conception is born; the SAMs without a "classical" fire control radar (or guidance station.) The first of such system appeared in the first decade of XXI. Century the NASAMS.

The "classical" SAM systems use for target acquisition and target tracking (missile guidance) different equipment. For example the 5N63S RPN (Flap Lid) is the fire control radar of the S-300PS system while it has two more additional radars, one for low level (5N66M NVO / Clam Shell) and another for med-hi altitude target acquisition (5N64S RLO / Big Bird.) See in the chapter about S-300/400 family.

Missiles of all classical SAM systems demand very frequent or continuous target illumination in terminal phase because of the RCS/SARH/TVM/SAGG guidance. The new type of SAMs because of their ARH guidance demands only MCG signals therefore much less frequent target update is needed. A single relatively fast scanning radar is enough for supplying the missile with MCG and is suitable also for target acquisition. In terminal phase ARH guided missiles use their own onboard radar for target illumination therefore dedicated fire control radar for the battery is not needed.

Before anybody call the Patriot "not a classical SAM" because of its single radar it has to be noted in terminal phase Patriot missiles demands very frequent target illumination; therefore regardless of a single radar Patriot has a guidance station for its TVM guided missiles. In PAC-3 configuration with ARH guided MIM-104F missile is partially became similar to concept presented above but PAC-3 has very short range and it is a dedicated ABM missile.

In fact the failed Dal[1] system was designed without guidance station about 60 years ahead before the first similar system. It was designed with very large ARH guided missiles and a large rotating radar complex but it was way too complex in the '50s. The Dal system is briefly mentioned in the chapter about S-200 (SA-5).

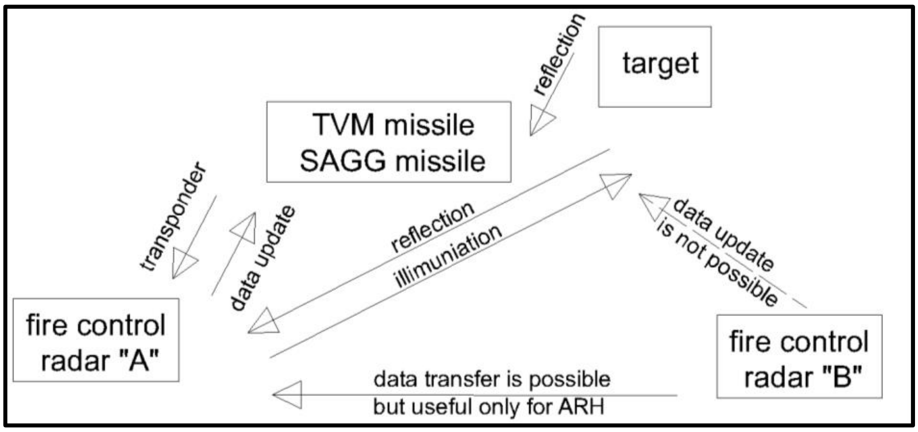
Why is required ARH guided missiles to discard the dedicated fire control radar? To answer this question a bit deeper explanation is needed concerning on Patriot and S-300 family.

The problem is the principle of TVM/SAGG guidance and their technical limitations. In the chapter about different guidance types is mentioned some SAM system use antennas rear section of the missile determining the distance between the missile and fire control radar (guidance station) with radio transponders. The missile is able to communicate with the battery in case the rear of the missile looks within a certain angle towards to the battery (because of antenna power and characteristics limitations.) Both TVM and SAGG are combined guidance methods (partially RCG and SARH). This simply prevents to get data from other guidance stations during the flight because only the point of launch is in good direction comparing to the missile. The missile data receiving capability is not omnidirectional.

The ARH guided missiles need mid-course updates (MCU) – especially at longer range engagement – therefore they suffer from the same limitations as TVM/SAGG guided missiles concerning on data transmission, omnidirectional receiving is not possible only the launching battery can send data. This means if the launching battery is part of a network and can receive target data for any other source it can forward to the ARH guided missile.

This "receive and feed" method does not work with SAGG or TVM because the transponder on the missile is required for guidance the same radar has to track both the target and missiles.

[1] *http://simhq.com/forum/ubbthreads.php/topics/4236786/all/Soviet_PVO_SAM_systems_develop*
Besides the Dal other failed SAM projects are in the topic which never entered in service.



In the chapter about S-300 family was mentioned USSR lost the area denial capability against of the low level targets when the low level cruise missile appeared in the inventory of the USA. With any of the Cold War SAM systems area denial capability is not possible against low level targets because of the terrain and horizon issue. In rare cases is possible to have large engagement zone but only in certain directions in case a SAM is deployed on a top of a hill or mountain but even in this case many time the surrounding terrain features restrict the line of sight (LOS) in other directions.

With ARH guidance and multiple target acquisition radars is achievable launching missile over the horizon comparing to the location of the launcher and target especially if the additional radar(s) are airborne radars. The over the horizon engagement capability is available[2] only for USA with E-2D and F-35 combining with SM6 missile but in the not distant future it seems possible with S-400 and S-350 Vityaz with certain missiles in case of availability Beriev A-100 AWACS. (In theory Buk-M3 and A-100 already has this capability.)

Below are explained the main differences between Cold War classical SAM, these consequence of different approach are described through the NASAMS/NASAMS2, S-350 Vityaz and ASTER 30-SAMP/T systems.

Because of the restricted firing arc of SAMs (assume just as example the S-300 and Patriot) they could be attacked outside of their engagement arc regardless of their multiple target and fire channels. Their lots of missiles and target channels make “only” much harder to attack from a single major direction but from another direction they are still vulnerable. In case opponent is able to initiate a coordinated attack from two very different directions even the S-300 and Patriot level SAMs can be destroyed with advanced anti-radiation missiles which are able to use side lobes o back lobes of the radar. (The mid ‘80s AGM-88 HARM was able to use side lobes.)

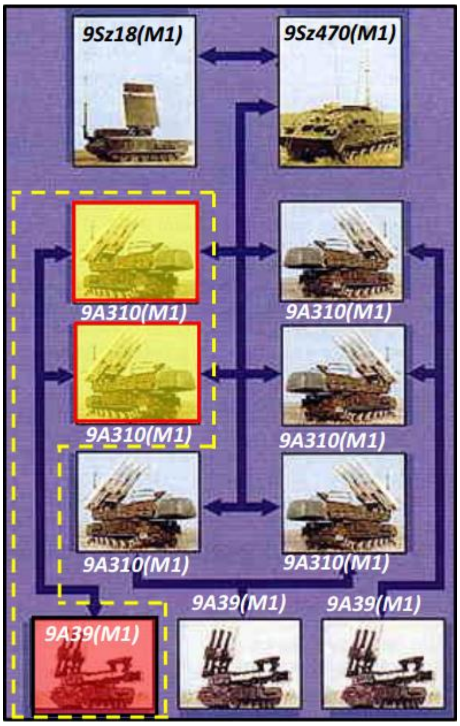
Because of this vulnerability was developed for close defense the Pantsir-S1 SAM (SA-22). The S-300/400 family units got the first Pantsir-S1 units from 2010. The long range army SAM the S-300V/VM could be defended by the 9K331 Tor-M1 (SA-15) SAMs or 9K37 Buk-M1/2/3 they use the same IADS system. (See later in more detailed the Russian army air defense systems.)

[2] *In 2018.*

Another vulnerability of classical SAM system is their structure the proximity of radars and launchers which are concentrated on the same location. If any EW asset is able to locate the fire control radar or target acquisition radar of a battery it is sure launchers and the equipment of the whole battery is nearby.[3]

If the type of the fire control radar can be determined by its emission the engagement zone of the system can be estimated which make easier to plan the counter actions against it and also can be estimated the time before any launched missiles from the battery reaches the attacking airplanes. In best case attackers can decide to stay away from the threat by knowing its location and type.

Another major disadvantage of guidance station conception the SAM battery is totally dependent from the fire control radar. If the fire control radar (the guidance station) is destroyed or disabled the battery is defenseless. Without the fire control radar the battery has 0 combat potential regardless the rest of equipment in the battery is intact the rest of the battery can be destroyed because their location is more or less known, they are very close to the fire control radar. (Some hundreds meter the max distance.)



Of course designers were aware of disadvantages and tried to solve when became possible within “reasonable”[4] cost. This is clearly visible on the structure of mid/late ‘80s 9K37 Buk-M1 (SA-11) radar guided Soviet army air defense system.[5] The designers increased dramatically number of fire control radars and integrated into missile launchers (TEL, *transporter erector launcher*) creating the TELAR (*transporter erector launcher and radar)* conception.

More radar means more target channels and each fire control radar can be used independently which means a single Buk-M1 battery is able to engage targets in any direction with each target channels (radar). If one TELAR is destroyed a single fire unit still has one more the fire unit retains at least a part of its combat potential. (The fire unit is shown with dashed line on the image right, one battery consist three fire units.)

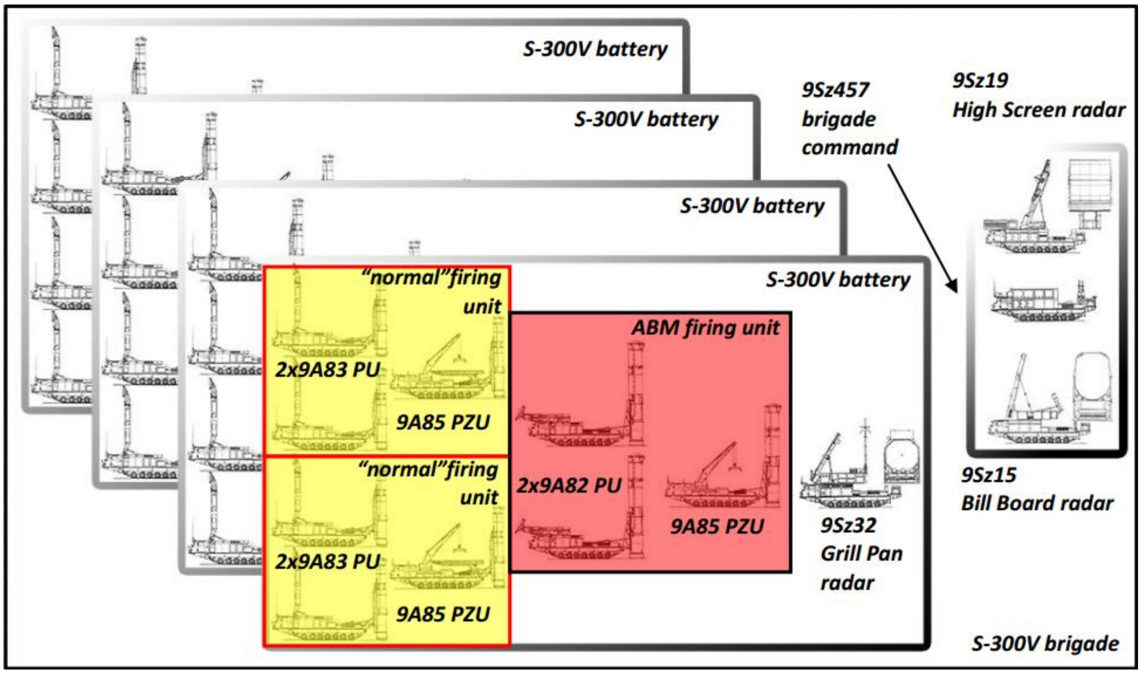
At first sight the S-300V/VM has redundancy because of TELARs but this is not true because without the 9S32 SNR (Grill pan) radar the battery is not operational. The PU vehicles provides the terminal phase CW illumination for SARH missiles but for mid-course guidance the 9S32 radar is required.[6]

[3] *Non export S-300/400 variants are different because the command battery target acquisition radar is not part of the missile battery but because of the modular structure missile batteries also can have 360 degree scan radars. See in the chapter about S-300/400 family.*

[4] *The Buk is a very expensive system regardless its fire control radar has significantly less range as contemporary S-300 variants or S-200 had.*

[5] *See later in more detailed in another chapter.*

[6] *See later in more detailed in another chapter.*



The conception of the S-300V is very similar to AEGIS which also uses different radars for target acquisition and MCG support and dedicated CW illuminators. The naval AEGIS and AEGIS-like systems have omnidirectional launch capability because of the 4 electronically scanned target acquisition radars (and in the case of the AEGIS) parabolic CW illuminators. See in chapter of naval SAMs

The examples above concerned on the most advanced SAMs in the late '80s and '90s but their upgraded variants are in service today (Buk-M3, S-300VM) and they will be for decades. It is worth to compare the new kind of SAMs much more older SAMs for example the 2K12 Kub (SA-6) which has only a single target channel.

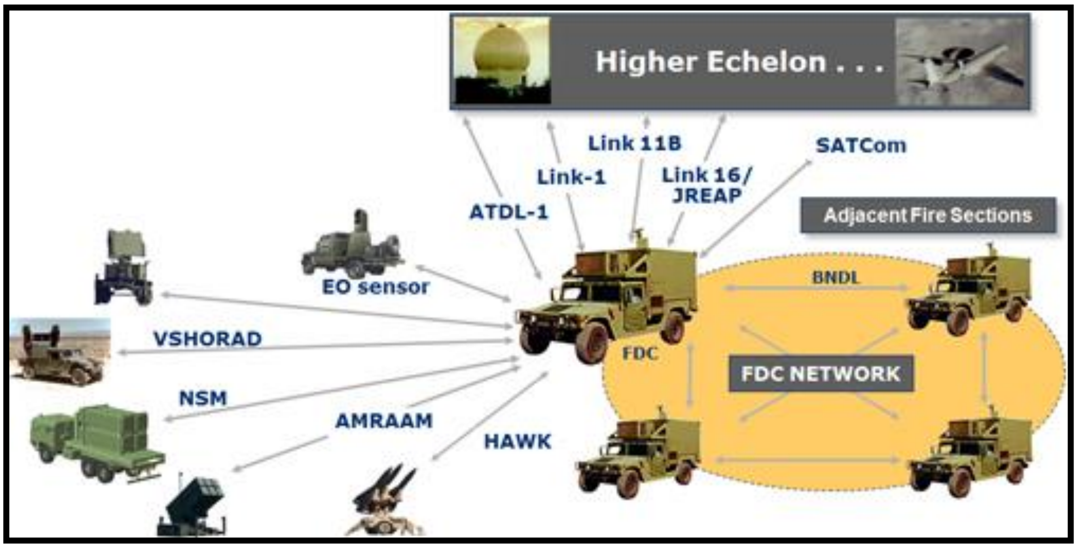
The first SAM system without a dedicated fire control radar was the NASAMS. The capability of the system is described with AIM-120C-7 type of missile but longer range missiles are also available such as the ESSM or AMRAAM-ER for NASAMS2.[7] Despite the longer range missile currently only AIM-120 AMRAAM is used for operational units. (2018) The NASAMS2 is able to use IR guided missiles with LoAL capability such as IRIS-T and AIM-9X Block II. The LoAL capability is needed for IR missiles because they are launched from closed container which makes impossible to lock the target with seekers of the missiles before the launch.

The main elements of NASAMS are the followings:

- AN/MPQ-64 Sentinel, S band, 360 degree scan 3D target acquisition radar. It is mechanically scanned in azimuth (rotation) electronically scanned in elevation. The radar has towed and self-propelled variant either. One battery can have more than one radar.
- Electro-optical (EO) target tracking and distance meter unit, one battery can have more than one EO vehicle.
- Fire Direction Center (FDC), one per battery.
- Missile launcher, it can be towed or self-propelled either, maximal quantity is 12/battery, each launcher has 6 AIM-120 missiles in containers.

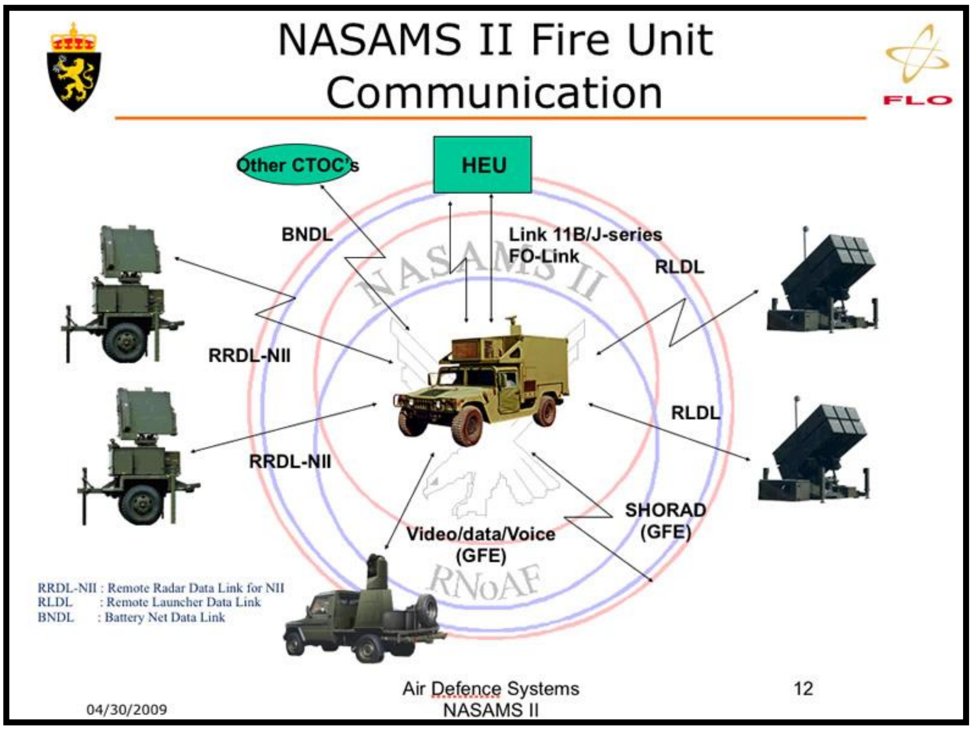
[7] http://www.raytheon.com/capabilities/rtnwcm/groups/public/documents/content/nasams_pdf.pdf
https://www.youtube.com/watch?v=AD70rPjLa9w

The operational method of the NASAMS is completely different from all previous SAM system. The AN/MPQ-64 radar or radars do not have to operate continuously if there are more or are other radars which can feed with target data the NASAMS via FDC. Because the Sentinel radars are only target acquisition radars they do not have to be on the same location as the launchers only the requirement of data link restricts the possible deployment locations. In case of flat terrain with small antennas the distance between launchers and FDC can be 25 km but using satellite communication or airborne relays such as AWACS (A&EW) airplanes the distance can be much larger.



Schematics the operational principle of the NASAMS

For the AIM-120 or other ARH guided missile is enough to provide MCU/MCG data with about 1s intervals especially considering the kinematic range of the AIM-120. The FDC send the data towards to the launchers which forward the updated target coordinates to the missiles. The antennas on the AIM-120 in this case always are in good position comparing to the relay station it does not matter the location of the Sentinel radar(s).



Schematics the NASAMS.

Even if location of Sentinel radar(s) are known by any electronic warfare asset the location of the launchers remains unknown. They can be anywhere because of the structure and operational method of the NASAMS. This kind of operation makes incredibly dangerous the NASAM especially if the system is well supported with other longer range radars. The attacker has close to 0 information about the launchers especially if the high mobility of the launchers is used well. The attacking airplanes can be deep into the engagement zone of a NASAMS battery without having a clue about it.


NASAMS launchers, above left on self- propelled trun on right is the deployable variant.


AN/MPQ-64 Sentinel radar is on self-propelled and towed vehicles.

Another major advantage or ARH guidance is the 360 degree launch arc for every launcher. Without fire control radar missiles can be launched to any direction moreover as many missile can be launched as many targets are within the engagement zone. (Missile quantity = target channel quantity) A single launcher has as many target channel as an S-300 system but of course with much less engagement zone concerning to a single launcher.

The data link via FDC provides the possibility to get target coordinates from any asset which can feed data into the network. Even all of Sentinel radars are silent (is not turned on) or destroyed a NASAMS battery still can mean a threat if other radars – land based, naval based or even AWACS – is able to feed with information just the search/scan zone have to overlap with the engagement zone of the NASAMS.

The NASAMS cannot be suppressed or destroyed as way as “classical” SAMs even the Sentinel radar uses cm wavelength which makes it vulnerable to anti-radiation missile. Even the radars are destroyed the FDC and missile launchers remains intact therefore the battery still has at last limited combat capability as long as via data link the battery is supplied with target coordinates.

In extreme case the AIM-120 missiles can be launched coordinates which are forwarded by radio, target location is needed to determine azimuth, elevation and range comparing to a launcher. Because of the small range of the AIM-120 it small radar has chance to find the target because ground clutter is very unlikely and the nominal detection range against medium fighter sized target is about 10 km. Of course this kind of operation is very suboptimal but it is possible.

In more or less ideal conditions when NASAMS acts alone the first warning what an attacker experiences is short random search radar emission. After first detection it is possible to track the target with the EO (on left) unit within certain distance. After just only 10-20 seconds the first RWR detection the missile can be on the way to the target and the targeted airplane has no idea about it. In case of precise MCU/MCG coordinates the AIM-120 turns on the onboard radar only before 4-6 seconds before the impact. If the target distance is bigger the Sentinel radars can be detected. Even the radars are used for longer period is not any launch warning because comparing to S-300 the battery does not have dedicated fire control radar.

In best case NASAMS does not have to use any of Sentinel radars and other long range land based radar or AWACS can provide target coordinate which can be 100-200 km away from the battery deployment zone. Using this set-up and coordination missiles literally can come from "nowhere" is simply not any radiation from the battery itself which can be detected with RWR. (Except very low power and not continuous data link communication.)

Detecting the missile launch is very hard with any currently is service 4th generation fighters because many of them still do not have IR MAWS system which also have their own limitations. Only after the launch can warn the pilot and MAWS function is warn to a launch itself but it does not help to locate a missile launcher. (The F-35 with DAS + data link is able to do this.)

Detecting the launch with naked eye is very unlikely because the AIM-120 missile produces only very thin smoke trail or not at all and the missile engine burns out after 8-9 seconds. Only the dust is visible on the ground following the launch but from 15-20 km is very hard to spot a launch if the pilot has no idea about the launch and its bearing.[8]

Following the first missile launch maybe an AWACS, a JSTAR or any other EW/recon asset could locate a launcher but before the launch if the battery does not use its radar is close to impossible to do anything and finding the launchers.

All equipment of the NASAMS can be very mobile a larger transport helicopter can airlift them to anywhere (similar to HAWK) which means NASAMS launchers can be deployed in such locations which cannot be reached off road.

[8] https://www.youtube.com/watch?v=TVbqiy77aeU *AIM-120 literally does not have smoke trails.*
https://www.youtube.com/watch?v=CgMMC6PxE2U *is only a very small smoke the rest of trail is contrail and not smoke.*
https://www.youtube.com/watch?v=mhz4ZQMHeDw *the missile has quite strong smoke I have no idea why.*

NASAMS is partially suitable for area defense and area denial up to 10 km target distance even its nominal maximal range is only 20-25 km with AIM-120C-7 missile. Because of the scattered deployment locations of the missile launchers this missile kinematic range has to be treated in a very different way. A single battery with 6 launchers using partially overlapping engagement zones can defend even a 50-60 km radius zone with very high number of target channels. The 10 km maximal altitude literally covers 99% of tactical targets from low level cruise missile up to high flying airplanes.

The NASAMS is partially suitable for area denial against low level targets within kinematic range as long as has AWACS support with the necessary data link. With terminal self-guidance capability the terrain is not an issue LOS is not mandatory between a launcher and the target. With the forwarded target coordinates from the AWACS – which has much better picture as land based radars – the missile can intercept in terminal phase the target.

Of course this area denial capability even with lots of launchers is limited but are longer range missiles as option for NASAMS2 than AIM-120C-7. With longer range missiles such as AMRAAM-ER or ESSS Block 2 over the horizon engagement capability is achievable for NASAMS2.

Finland selected the NASAMS to replace 9K37M Buk-M1[9] (SA-11) system regardless NASAMS does not have real ABM capability and the missile kinematic range is much smaller (about half) comparing to the Russian SAM. (Against advanced TBMs even the Buk-M1 is useless its maximal target speed is 800 m/s) Considering the scattered deployment capability of the NASAMS with much less equipment is possible to have similar or even larger protected airspace with much more target channels. Also was a very crucial point for selecting the NASAMS the missile compatibility with F/A-18 Hornet. The NASAMS use the same missile what Finnish F/A-18 Hornet fleet only software modification are needed for the application as SAM. This makes (partially) cost efficient. The cost of 4 NASAMS batteries was 346 million Euro.[10]

The survivability and flexibility of the NASAMS currently is unmatched because the system can be fully disabled only in case the FDC or all missile launchers are destroyed. The deployment location of FDC, EO unit and launchers are totally freely selectable they can be anywhere comparing to each other. Locating the elements of the battery is difficult because the FDC emits in very low power for very short time during data transfer which is not comparable to very powerful radar emission of classical SAMs during missile guidance.

Besides the advantage of conception of NASAMS it has to be noted the disadvantages which comes with the different approach; these are the followings:

- The AIM-120 missile is very expensive comparing to an SARH guided missiles. Depending on the political situation and the size of the purchase the unit cost of an AIM-120C-7 missile is about 1.5-2 million USD/missile. Above a certain missile quantity the cost of the whole package can be higher concerning to a defended area comparing to an SARH system

  (Of course the number of target channels cannot be matched even with SAGG/TVM guided very brutal and expensive S-300 and Patriot systems as well as the 360 degree launch arc.)

- Regardless the system provides a very good area denial capability against airplanes it is unusable in ABM role. The AIM-120 missile is capable to hit M3.0 speed targets but the problem is the kinematics of the missile and the Sentinel radar. The best what can be expected for a launcher to have self-defense capability with 0 km offset distance but this is also quite theoretical because as the NASAMS is

[9] About acquisition of SAMs system from Finland is a document in the attachment.
[10] It is not specified with or without one full load of missiles.

working. Very likely nobody ever can launch a TBM against a single launcher which has unknown position in most of the time.

- The Sentinel radar detection range is only 75 km against average size airplanes which also limits the deployment distance of the launchers from the radar. Because of reaction time to fully utilize the range of a 25 km range missile is about 40 km first detection range is necessary. If the launcher is away from radar 25 km it means the radar just barely provide this search range and coverage.

  (ABM role also demands longer range than the Sentinel if we assume a more suitable missile for the ABM capability.)

- The engagement range of a single launcher (~20 km) is limited comparing some other medium range SAM systems such as HAWK or Buk-M1 (35-40 km range.) Such range is achievable using AMRAAM-ER and ESSM Bock but in this case many Sentinel radars are needed because of the necessary search range coverage. With longer range missiles and only 1-2 Sentinel radars are not enough to fully utilize the capability of the longer kinematic range of the missiles. Much more quantity of radars or longer range radars are needed which has strong impact on tactics and cost either.
- The ARH guided missiles are “susceptible” to towed decoys as well as SARH, TVM and SAGG guidance which use mechanical scan and not PESA or AESA. In the future this issue can be solved because it has been manufactured ARH guided missile with AESA radar (AAM-4 in Japan) it is not impossible and currently towed decoys are not widely used and available on fighters.

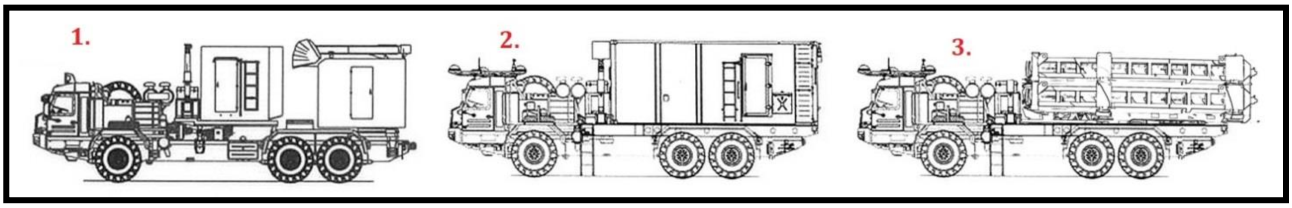
What changes in case NASAMS uses longer range missile than AIM-120C-7? Considering the relatively small engagement zone of AIM-120C-7 (20-25 km distance up to 8-10 km) the requirements of target tracking is not so serious concerning on continuous or longer period of radar usage because the flight time of A IM-120. Only for a very short time is needed ensuring the MCG/MCU the first 10 km flight distance is required about 15 seconds and total flight time is about 30-40 seconds. On the other hand if we consider the ESSM/AMRAAM/ER missiles as weapon the situation becomes more serious in longer range (~40-50 km) engagements.

The total flight time of the missile can reach 60-90 seconds for the longer range S-350 Vityaz and SAMP/T it can be 120-140 seconds. When target distance is so big short and less regular use of radar is not possible if we seek high hit probability. If the target is maneuvering in a long range engagement without proper MCU/MCG the missile can miss easily the target because being on wrong course and even after turning on its radar can’t find any target within the scan zone. After 60-120 seconds of flight the target location can deviate from the original intercept point with 10-20 km. Also has to be noted in case of long range engagement using the supplementary EO vehicle is not possible because of its more limited range.

NASAMS battery in operation near Helsinki on the screen of FDC are displayed the track of targets and other parameters. Launcher and radar locations are also visible on the screen.

For supporting the demands of longer engagements using larger and more powerful radar for longer period is the direct consequence. This change comparing to NASAMS makes more vulnerable the SAM system concerning on detection and ARM guidance if the radar of the SAM is within the beamwidth limitation of the anti-radiation missiles. Both the Sentinel and the multi-function radar (50N6) of the S-350 uses cm wavelength (X band). (Of course shooting down of ARMs is possible.)

S-350 Vityaz[11] is a similar new SAM system to NASAMS but currently (2018) it is not possible to deploy as such scattered way as the NASAMS is able to perform the whole battery is deployed around the 50K6 command control cabin. Below are the main elements of the Vityaz battery:



50R6 S-350 Vityaz

1. 50N6 MFR multi-function radar, 1-2 pcs/battery
2. 50K6 PBU command and control cabin,1 pc/battery
3. 50P6 PU launcher, 1-8 pcs/battery each with 12 pcs missiles

Regardless the S-350 uses ARH guided missiles the quantity of target channels are not equal with the quantity of missiles it has “only” 16 against airplanes each target can be targeted with 2 missiles (in total 32 missile channels) or it can have 12 target channels against ballistic missiles. Against BMs has less target channels (likely) because for accurate target tracking is more frequent illumination and higher elevation

[11] https://goo.gl/5kWtJd
https://thaimilitaryandasianregion.wordpress.com/2016/10/17/s-350e-vityaz-50r6-sam/
https://de.wikipedia.org/wiki/S-350
http://militaryrussia.ru/blog/topic-633.html

scan zone is needed comparing to airplanes because of the trajectory of BMs. Similar to NASAMS missile uses their own seekers only in terminal phase. The S-350 has the following missile types[12]

type	***weight***	***range***	***target altitude***	***target speed***
-	*kg*	*km*	*km*	*m/s*
9M96	333	1-40	0,005-20	4800 m/s (?)
9M96M 9M96E2	333	1-60 (?)[13]	0,005-20	4800 m/s (?)
9M96D 9M96E	420	120 km 30 km against BMs	00,005-30	4800 m/s
9M100 (IR)	140	10-15	0,005-8	1000

The engagement zone of the Vityaz against airplanes is 120 km. It can engage supersonic missiles such ARMs (similarly to S-300 or Patriot) and it has ABM capability against very high speed BMs similar to Patriot PAC-3.

The composition of a battery is much closer to a “classical” SAM system comparing to the NASAMS but still provides the ABM capability but similarly to other SAMs comparing to engagement zone against airplanes the ABM engagement zone is much more restricted only 30 km. The much more powerful 50N6 MFR is one of the key element for ABM capability.

Besides the ARH guided missile the S-350 for self-defense has the 9M100 type IR guided missile very likely against helicopters and UCAVs as a cheaper and cost effective missile. All of the missiles has similar pulse solid propellant rocket motors rocket engines as the PAC-3. The S-350 in other area also represents a new level similar to Patriot is has fully automatic mode where the operators just supervise the operation of the battery. All vehicles are self-propelled the deployment time of the battery is 5 minutes.

The Vityaz in theory is capable to perform area defense considering low flying cruise missiles as target if the cooperation is possible with A-50/A-100 AWACS airplane. It will be even more suitable when will be possible deploy the launchers far from the 50N6 radar. If any other radar or the AWACS can feed with target coordinates (very likely) the S-350 is able launch missiles targets over the horizon because in terminal phase missiles can lock on targets without having LOS between the 50N6 radar and the targets.

For increasing the area denial capability the system will have communication mast units which looks remarkably similar to antennas of Vektor and Senezh IDAS. These will make possible similar scattered deployment to PAC-3 or NASAMS. (Except comparing to NASAMS the radar is way too expensive to provide more than 1-2/battery.)

[12] Are many different sources and many of them contains contradictory data. The values in chart above were derived from range values with indicated the best match with missile size, type and ranges.

[13] In Russian marketing materials the 9M96E has 60 km range.

Elements of an S-350 battery and above left is the 5Ja62 Tskiloida relay antenna system on right side are the communication mast of the Vityaz.

Russia already possesses A-50/A-100 AWACS the first even in late ‘80s configuration was able to establish data link with IADS of PVO moreover with the most advanced IADS elements army air defense on army level (9S52 Polyana-D4, Buk-M1) or front level (9S457 KP, S-300V), see later.

Another additional and possible feature for S-350 to keep the RLO (Big Bird) radar of S-300PS units will be replaced first with the Vityaz. The RLO could provide 360 degree long range target acquisition capability – at least against airplanes at med-high flying targets – without using the 50N6 radar. With very hard over estimation we can assume using only target coordinates from the RLO the ARH guided missiles could be launched as the Sentinel radar acts for NASAMS. The major difference it the wavelength of RLO (meter range) which makes resistant to AGM-88 HARM which cannot target such long wavelength radar.

The way how will exactly replace the S-350 the S-300PS is currently unknown very likely two battery size S-300PS regiments will be replaced at the following locations:

- Kaliningrad, 2 regiments, 4 batteries
- St. Petersburg, 4 regiments, 8 batteries
- Engels, Yekaterinburg, Samara, Voronezh, Khabarovsk ,Komsomolsk, Irkutsk, Achinks, each with 1 regiments, 2 batteries

2 S-300PS have 96 missiles (2 batteries x 12 launchers x 4 missiles) ready to launch which is identical the inventory of the S-350 (8x12).

1 complex of S-350 consists the following elements:

- 1 pc PBU command and control cabin
- 2 pcs MFR radar, 2 batteries
- 2x4 PU launchers, 2 batteries
- 96 missiles

The distance between the PBU and MFR can be 2 km between the PU and PBU is 2 km either. Between two PBUs (batteries) the maximal distance is 15 km with IADS antenna mast can be increased to 30 km which means if the mast if halfway between the batteries the two PBUs can be 60 km apart from each other. This feature very likely will be applied for PU which means the MFR-PU or PBU-PU distance can be increased.

Considering all of the features of the S-350 is less similar to NASAMS because of its range and lack of EO unit(s) and it does not have redundancy concerning of 50N6 MFR but likely because of the modularity of the system in theory this could be achievable. The main difference between classical long range SAMs of S-300 family and S-350 are the followings:

- Launch arc of S-300/S400 with SAGG guidance is only 90 or 105 degrees depending on subvariant while S-350 has 360 degree
- Instead 6/12 target channels the S-350 has 16.
- S-350 does not have dedicated radar (in case RLO of phased out S-300PS units won't be used)

The European SAMP/T[14] uses similar conception but it is rather closer to S-350 than NASAMS because it has ABM capability against 600 km range TBMs, it has only a single type of radar with more larger and powerful missiles.

The main elements of the SAMP/T is the Aster 15/30 missiles, the Arabel[15] multi-function radar and the missile launchers. It was a very important design requirement for the SAMP-T to be able to operate with other NATO SAM system. Basically it uses the conception of FDC and data link which has been explained at chapter of Patriot.[16]

The launcher vehicle of the SAMP/T carries 8 missiles, in ready to launch state the container is set vertically at the rear of the truck. A single launcher can launch all of its missiles within 10 seconds in two salvos. If the system uses different launchers the minimal interval between two missile launch is 0.5 seconds.

The SAMP/T system can operate with two different missiles the Aster 15 and Aster 30 the second is the larger with a solid booster first stage. The design of the stage and its separation is different and more

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[14] https://goo.gl/wUUhD4
https://goo.gl/dxG63h
http://www.army-technology.com/projects/aster-30/
https://www.youtube.com/watch?v=0Nk3HV-dDcU
http://www.military-today.com/missiles/sampt.htm

[15] http://www.eurosam.com/products/eurosams-building-block/arabel/

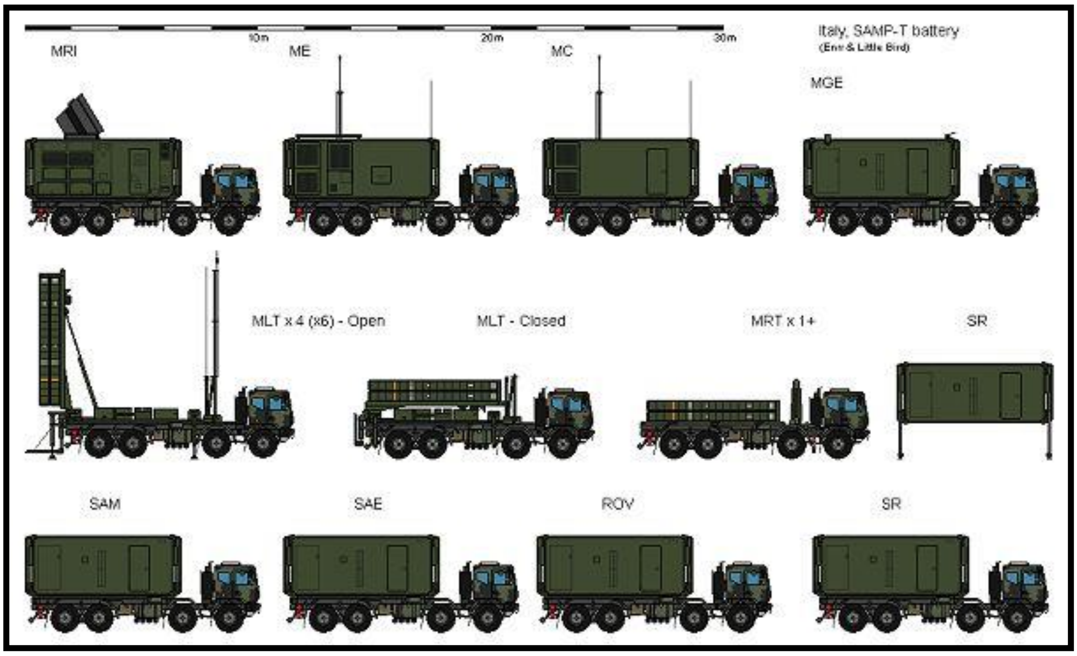
[16] *Hungarian modernized 2K12 Kub-M3 variant has the capability to be part of NATO SAM network very likely Hungarian Kub systems are the most advanced Kub variants in the world.*

advanced comparing to old Soviet two stage SAMs because the missile can perform turns even before the stage separation.

Just for a quick comparison. The old S-125 Neva had less than 25 km engagement zone with a 900 kg missiles while the Aster 30 launch weight is only half 450 kg and its range is 100 km if targets are flying higher than 3 km. The burnout speed of the missile is 1400 m/s (Mach 4.5) against low flying targets the range is 50 km. The increased range is achieved not only by the more advanced propellant, lighter airframe and smaller diameter but the guidance make possible the similar ballistic trajectory as we can see at S-300/400 family or the Patriot while because of the guidance method limited the trajectory of the Neva.

The Aster missiles use combined INS + ARH guidance with the usual MCG/MCU support by the Arabel multi-function radar via digital data link. Similar to 50N6 radar of S-350 the Arabel radar provides the 360 degree long range target acquisition. It is also similar feature the restricted quantity of target channels, up to 10 targets is possible to guide missiles. (Some sources mention 16 channels but in the linked video mentions only 10 is specified.)

The capability of shooting over the horizon seems possible even without stating the capability because of the interoperability capability with existing NATO assets (Patriot, other EW radars and E-3 AWACS) with the longer range Aster 30 missile. Scattered deployment of the launchers is technically possible the distance between the radar can be 25 km (some sources mention only 10 km.) The main elements of a battery below.



MRI ***Arabel multi-function radar***
ME ***Fire distribution / control center***
MGE ***Generator unit***
MLT ***missile launcher (4-6 pcs / battery)***
MRT ***missile loader vehicle (2 pcs / battery)***
SAE & SAM ***repair and maintenance vehicles***

Above is the missile launcher in deployed state and the Arabel radar.

Launch of the two stage Aster 30 missile.

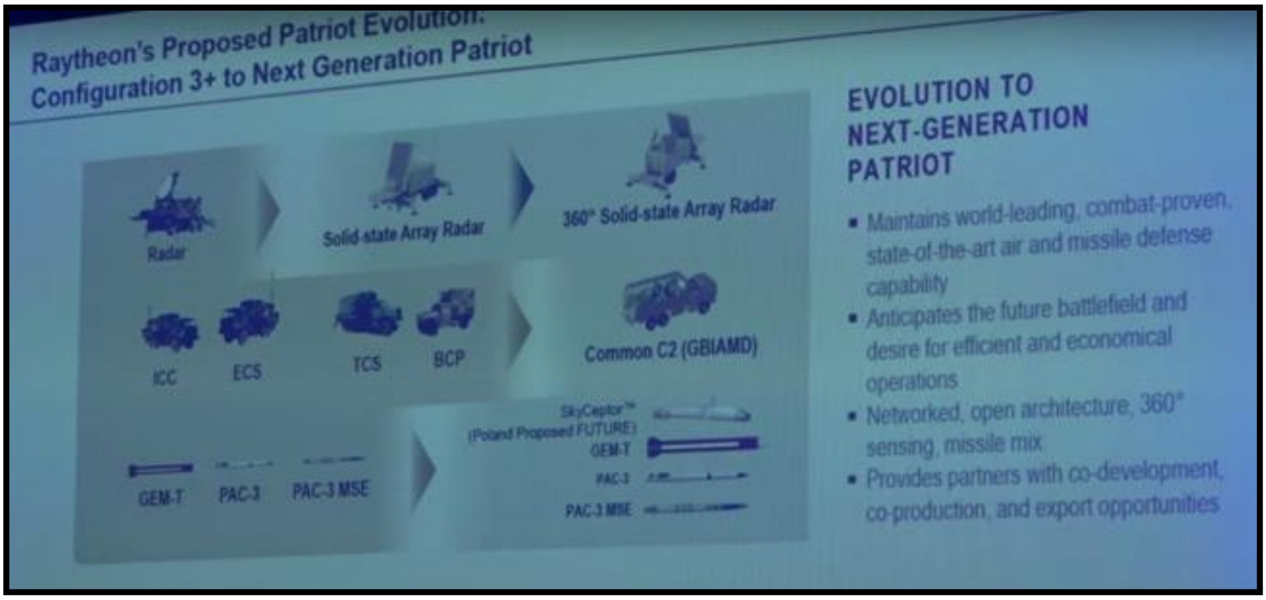
The proposed Skyceptor SAM system also brings a new feature which maybe will the path of the future; the system can considered as the latest iteration of Patriot SAM family. The missile of the new system is based on the Israeli Stunner missile with combined AESA ARH and IR guidance which is very likely designed against the towed decoys thanks to the additional non-radar based sensor and the quick scan capability of the AESA radar comparing to mechanically steered antennas.

Comparing to “classical” Patriot variants is also a major difference the two stage missile (similarly to SAMP/T) and the 360 degree scan capable long range radar which eradicates the 270 degree set limitation of the older Patriots. Instead the ICC and ECS only a joint unit would serve the function of these (Common

C2, GBIAMD). The Skyceptor SAM currently is only a “paper design” SAM system so far only was offered to Poland but it has not been produced a single unit.

Thanks to the large two stage missile with 400 km (!) range in theory this system would have the largest engagement zone at the time of IOC. The system partially also can be considered similar to NASAMS because of the base conception even the first Patriot variant. As long as other assets (best is AWACS) can provide radar picture about the tactical situation even in case of long range engagement using the land based fire control radar is not necessary (depending on other factors) if lots of radars are available in a network via digital data link.

Above is the Stunner missile this would the base of the proposed missile; the very distinct nose shape of the missile is the result of the combined ARH + IR guidance.



A brief list about features and capabilities about the next generation Patriot SAM.

Using examples the SAM systems above we can see area denial capability becomes possible even against low flying targets in case of presence of AWACS airplanes which can provide very good low level search capability even at long range.

The extreme prediction and consequence of the new type of long range SAMs in defense fighters in some cases are simply not necessary if we think in very extremes. The land based launchers can get all the data from land based radars and AWACS. In case the AWACS is close to the SAM it can protect even from long range air to air missiles or extreme long range SAMs by shooting the incoming threats it has already

happened such missile launch. [17] Of course this conception comes with a very high cost because of the 0/24 AWACS presence – to have area denial capability against low flying targets – and long range expensive missile but the provided capabilities are phenomenal (in theory). Using such very expensive system against every target can be overkill and way too expensive.

The 9S52 Polyana-D4 can cooperate with A-50 AWACS singe the late '80s and the most advanced Buk-3M has ARH guided missiles. In theory with A-50/A-100 and scattered deployment a Buk-M3 regiment – see later at army air defense chapter – can cover a huge area and also we can see this conception with S-400 and the 40N6 missile.[18] The 380 km range is very theoretical even with the new missile because of the radar horizon but in case of presence of AWACS the 380 km kinematic range of the missile can be utilized. With AWACS and ARH guided missile the area denial capability can be restored even considering low level cruise missile targets as long as the reentry stage heating issue does not restrict the engagement altitude.

The another major improvement which is the consequence of towed decoys the application of the AESA or PESA radar technology for ARH guidance and also is possible to use PESA antenna array for SAGG/TVM guided missiles.

[17] *http://www.israelnationalnews.com/News/News.aspx/227028*
http://www.thedrive.com/the-war-zone/8404/arrow-missile-intercepts-syrian-sam-fired-at-israeli-jets-following-strikes

[18] *40N6 is still not in service. (2018)*